APPENDIX C
EVALUATION OF INDOOR INHALATION PATHWAY

The procedure used to quantitatively evaluate the indoor inhalation pathway is presented in this appendix. Figure C-1, same as Figure 6-1, shows the step-by-step approach to evaluate the indoor inhalation pathway. Each of the steps illustrated in the flowchart is described below.

C.1 STEP 1: EVALUATE WHETHER THE PATHWAY IS COMPLETE

The objective of this step is to determine whether any of the following indoor inhalation related pathways are complete:

- Indoor inhalation of volatile emissions from sub-surface soils, and
- Indoor inhalation of volatile emissions from groundwater,

Determining whether the indoor inhalation pathway is complete typically occurs during the development of the exposure model, (refer to Section 6.1) and is based on a combination of site-specific information and professional judgment. A few conditions under which these pathways would not be complete include:

- All chemicals of concern (COCs) at the site are non-volatile. Chemicals with a dimensionless Henry's Law constant of 1×10^{-4} or less and a molecular weight greater than 200 are generally considered non-volatile (US EPA, 1996). If volatile chemicals were not present, the indoor inhalation pathway for both current and future conditions would be incomplete.

- For current conditions, if the soil and groundwater within a horizontal distance of 25 feet of a structure are not affected by volatile COCs, the pathway would be considered incomplete. Such a condition would be expected to occur where the release occurred away from existing buildings in a hydraulically down gradient direction and groundwater below the building was not otherwise affected.

- For future conditions, anticipated site-specific land use and development must be considered in determining whether a building might be built on-site. The indoor inhalation pathway would be incomplete if such conditions prevent or prohibit the construction of a building on-site. An example of such a condition would be a spill over a pipeline right-of-way.

- If all affected and potentially affected existing and planned future buildings include a vapor barrier that prevents the intrusion of vapors into a building or a passive or active venting system that prevents the buildup of vapors into a building, the indoor inhalation pathway shall be considered incomplete. Note, however, that the use of barrier or venting systems will be approved by MDNR only in combination with an appropriate activity and use limitation (AUL) that will ensure the long term operation and maintenance of the system.

C.2 STEP 2: PERFORM A TIER 1 RISK ASSESSMENT

If the indoor inhalation pathway is or will be complete under current or reasonably anticipated future conditions, the evaluator must perform a Tier 1 risk assessment. A Tier 1 risk assessment requires that the representative soil or groundwater concentrations be compared with the relevant Tier 1 risk-based target levels (RBTLs). The RBTLs for various receptors are tabulated in Tables 7-1(a) through (f).

C.3 STEP 3: DETERMINE THE NEXT STEP: TIER 2 RISK ASSESSMENT OR RISK MANAGEMENT PLAN

Based on the comparison in Step 2, one of the following two alternatives is possible:

- **Tier 1, Alternative 1:** Representative soil and groundwater concentrations are below Tier 1 RBTLs, in which case no further evaluation of the indoor inhalation pathway is necessary.

- **Tier 1, Alternative 2:** Representative soil and groundwater concentrations exceed the Tier 1 RBTLs, in which case one of the following two options must be selected:

    - **Tier 1, Option 1:** Adopt Tier 1 RBTLs as the cleanup levels and develop a risk management plan (RMP) to achieve these levels.

    - **Tier 1, Option 2:** Perform a Tier 2 risk assessment (Step 4).

C.4 STEP 4: DEVELOP SOIL AND GROUNDWATER SSTLs

Using the procedures described in Section 8.2, Tier 2 Site-Specific Target Levels (SSTLs) for soil and groundwater must be developed for each volatile COC and complete route of exposure. The SSTLs should be compared with representative concentrations, and the path forward determined as discussed in Step 5.

C.5 STEP 5: DETERMINE THE NEXT STEP: NO FURTHER ACTION OR SOIL VAPOR MEASUREMENT

Soil and groundwater SSTLs developed in Step 4 should be compared with the site-specific representative concentrations to determine the next step. Based on the comparison, one of the following two alternatives is possible:

- **Tier 2, Alternative 1:** Representative soil and groundwater concentrations do not exceed the Tier 2 soil or groundwater SSTLs. In this case, provided MDNR determines that the data used in the evaluation was adequate and appropriate, no further evaluation of the indoor inhalation pathway will be necessary.

- **Tier 2, Alternative 2:** The soil or groundwater representative concentrations exceed the SSTLs, in which case one of the following two options is available. Please note that, nationwide, considerable developments are currently underway in the development of soil vapor measurements. The entity performing the work is requested to familiarize themselves with the current-state-of the practice and not rely solely on the guidance provided below:

    - **Tier 2, Option 1:** Adopt the Tier 2 soil and groundwater SSTLs as the cleanup levels and develop a RMP to meet the cleanup levels.

    - **Tier 2, Option 2:** Develop and implement (upon MDNR approval) a work-plan to conduct a comprehensive soil vapor survey (Step 6).

C.6 STEP 6: SOIL VAPOR TARGET LEVEL DEVELOPMENT AND SOIL VAPOR MEASUREMENTS

Develop a work plan to perform a soil vapor survey as per the brief guidelines provided in Section C.7. The work plan should be implemented in a timely manner upon receiving approval from MDNR. Upon completion of the field measurements, representative soil vapor concentrations shall be compared with the Tier 2 soil vapor target levels developed using the computational software. Specific equations used to estimate the soil vapor target levels are presented in Appendix B.

- **Tier 2 Soil Vapor, Alternative 1:** If the soil vapor measured concentrations do not exceed the Tier 2 soil vapor target levels, no further evaluation of the pathway is necessary. This assumes that sufficient soil vapor data is available.

- **Tier 2 Soil Vapor, Alternative 2:** If the soil vapor measured concentrations exceed the Tier 2 soil vapor target concentrations, one of three options is available:

    - **Tier 2 Soil Vapor, Option 1**: Develop a RMP work plan to meet the soil vapor target levels. Upon completion of the RMP, confirmatory soil vapor measurements shall be required.

    - **Tier 2 Soil Vapor, Option 2**: Develop a work plan to perform a Tier 3 risk assessment. A Tier 3 risk assessment may include several options. These include re-analysis of soil vapor data using an alternative model or performing indoor air sampling.

C.7 PROTOCOL FOR THE MEASUREMENT OF SOIL VAPOR LEVELS

The intent of measuring COC concentrations in soil gas is to obtain spatially and temporally representative values that can be used to estimate receptor risk. Soil vapor concentrations at a site are affected by a number of factors, including (i) atmospheric conditions (temperature, pressure, moisture content etc.), (ii) soil stratigraphy, (iii)

heterogeneity of soil, (iv) location of source, (v) age of the spill, and (vi) biodegradability characteristics of the soil-chemical "system."

To the extent that these factors cause spatial and temporal variations, soil vapor concentrations can be highly variable. Thus the MDNR does not consider a single soil vapor sampling event to be adequate for the characterization of COC vapors. Measurements must be made over time to represent the range of possible site conditions. Thus MDNR will require that a minimum of two sampling events be conducted at different times of the year (e.g., winter and summer). At sites where seasonal water table fluctuations are significant (> 5ft.), measurements must be made both when the water table is high and low.

The evaluator must develop a work plan to satisfy the above objectives, submit the work plan to MDNR, and implement the fieldwork only upon written receipt of MDNR's approval of the work-plan. The work-plan shall include, but not necessarily be limited to, the following:

- The location where samples will be collected,
- The depth where samples will be collected,
- The number of samples to be collected,
- The frequency of sampling,
- Soil gas measurement techniques and laboratory analysis procedures, and
- QA/QC procedures.

Each of these is discussed below.

C.7.1 Location Where Samples will be Collected

The evaluator shall consider the following when siting soil gas borings:

- The locations of the point and area of release,
- The location of the highest concentrations of volatile COCs in ground water,
- The location(s) of existing on-site building(s),
- The location(s) of potential future on-site building(s),
- The location(s) of existing off-site buildings, and
- The location(s) of potential future off-site building(s).

Samples should be collected around the footprint of all existing or potential future buildings potentially affected by the release. In all cases, at least one soil vapor boring/implant shall be located in the source area or areas (i.e., the area of most impacted soil and the area above the most impacted groundwater). Sampling at off-site locations will only be required if COCs have migrated, or are likely to migrate, off-site in soil or groundwater. Except in the smear zone, soil is typically not impacted off-site.

The entity performing the work shall very clearly indicate the proposed locations of soil vapor borings/implants on a site map and explain the rationale for each location.

C.7.2 Sampling Depth

The depth at which samples will be collected depends on the depth to soil contamination and the depth to groundwater (the latter only if vapors emanate from groundwater). The sampling system should consist of nested soil gas implants. Unless the depth to contamination (soil or groundwater) is very shallow (e.g., < 3 ft), a minimum of two soil gas samples at varying depths shall be collected. In all cases, one sample should be collected no more than 3 feet below the foundation of the enclosed space or potential future enclosed space. For structures having basements, soil gas samples should be collected below and adjacent to the basement wall. Possible locations of sampling points are shown in Figure C-2. If COCs exist under an existing building, the collection of samples below the building might be necessary, in which case boring through the foundation slab or drilling horizontal borings might be necessary to access soil below the slab.

C.7.3 Number of Samples to be Collected

As in the case of site characterization, the number of soil gas samples to be collected will depend on site-specific conditions. For existing buildings with soil or groundwater contamination below them, four borings, one on each side of the building, are required. Additionally, locating one or more borings within the source area might be necessary. As mentioned in C.7.2, samples should be collected at multiple depths within each boring.

C.7.4 Soil Gas Measurement Technique and Analysis

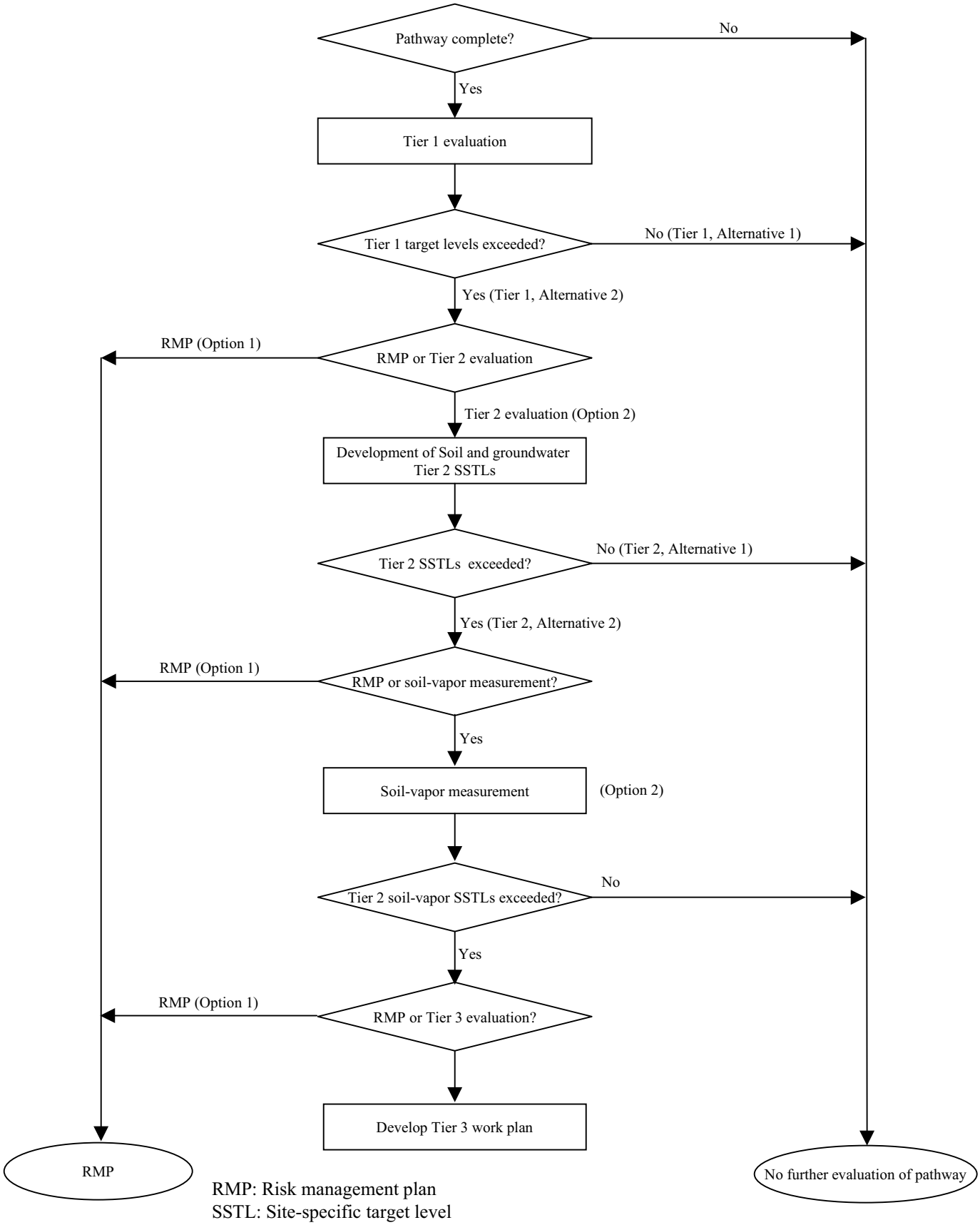
As mentioned above, soil vapor data must be collected on multiple occasions. Hence, soil implants used for soil vapor sampling should be sturdy and their location clearly identifiable so that they can be reliably used over an extended period of time. Soil implants may be installed using either direct push technology or (2”diameter) hollow stem augers. Care should be taken to install the implants in a manner that minimizes soil disturbance.

Soil vapor samples should be collected in a tedlar bag or an evacuated Summa canister and analyzed for the volatiles of concern. The decision whether to use a tedlar bag or a Summa canister should be based on the detection limits associated with the sampling and corresponding analytical methods. The method that results in detection limits equal to or less than the target levels must be used.

Prior to collecting the sample, the implants and tubing should be thoroughly purged to ensure that the sample sent for analysis is truly representative of the formation being sampled. For petroleum product spills, COCs include benzene, toluene, xylenes, ethylbenzene, MTBE, and naphthalene. The entity performing the work may also

analyze the vapor samples for oxygen, carbon dioxide, nitrogen, methane and other indicators of the biodegradation of hydrocarbon vapors, though these analyses are not required. Measurements of these compounds may be used to demonstrate the occurrence of natural attenuation.

In addition to the above, soil samples should be collected as close to the vapor sampling implants as practical. Ideally, soil samples should be collected during installation of the implants. Soil samples shall be analyzed for soil geotechnical properties (refer to subsection 5.6 of this document) and the volatile COCs. If groundwater is the anticipated source of vapors, a groundwater sample shall be collected below the point where soil vapor samples are collected.



RMP: Risk management plan
SSTL: Site-specific target level

Figure C-1. Flowchart for Indoor Inhalation

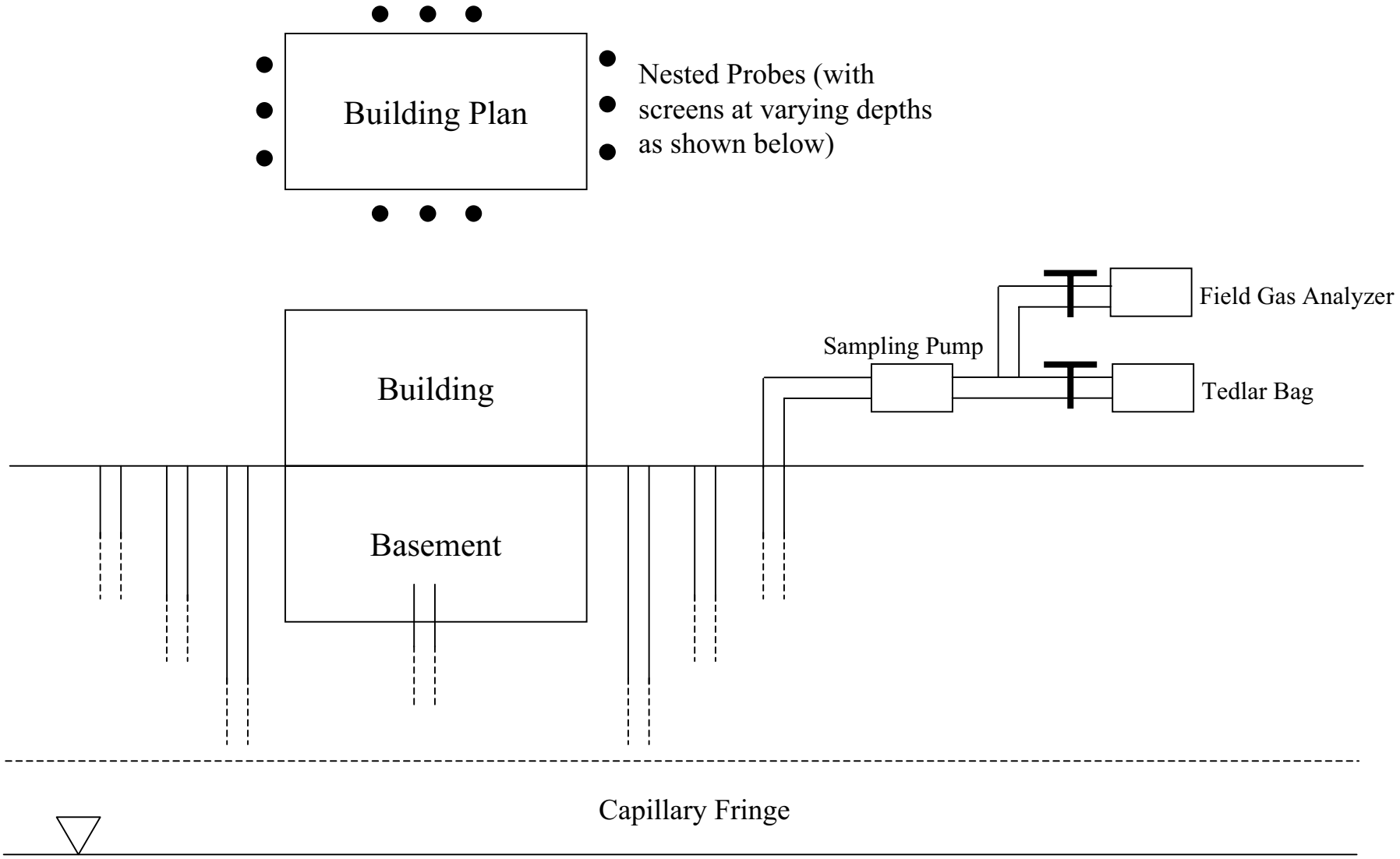


Figure C-2. Location of Nested Soil Gas Probes